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Environmental Criteria Determination Program, an Overview

by
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Range Department

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NAVAL WEAPONS CENTER
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FOREWORD

This report provides an overview of efforts to date on a program aimed at defining the military environment as it pertains to air-launched tactical weapons. The program described was initiated in 1967 under sponsorship of the Naval Air Systems Command. Efforts are continuing in this area with FY 1981 funding provided under AirTask A03W3300/008B/9F3/300000. Included in this report is a complete listing of those documents published to date which pertain to this subject.

Approved by
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8 April 1981

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(U) *Environmental Criteria Determination Program, An Overview*, by Howard C. Schafer. China Lake, Calif., Naval Weapons Center, April 1981. (NWC TP 6121, publication UNCLASSIFIED.)

(U) This report summarizes the environmental criteria determination program primarily in terms of efforts conducted to date to (1) define a viable philosophy for designing and testing materiel and ordnance, (2) measure and appropriately present in-the-field data, and (3) provide reasonable guidelines, tools and techniques for conduct of environmental testing more analogous to real world situations.

CONTENTS

INTRODUCTION

The mid-1960's brought to the fore the need to define the military environment as it pertains to air-launched tactical weapons. Navy and Air Force field failure reports, pilot combat debriefings, and field liaison-derived information consistently indicated the need for providing missile system designers with realistic environmental information. Such information, if provided in usable form and timely manner, could be easily integrated into the design phase of a system development.

In 1967, the Naval Air Systems Command (NAVAIR) initiated an environmental criteria determination program, under direct sponsorship of AIR-330, with guidance and objectives jointly agreed upon by the Associate Technical Director for Research and Technology, the Technical Director for Aircraft and Weapons, the Technical Director of the Armament Division, and their staffs. Exploratory development (Category 6.2) funding was considered appropriate for this program to assure that needed tools and techniques would be available by the time a program reached the development stage (Categories 6.3 or 6.4). Over the years, where advancement of this program was of parochial value, a number of specific Category 6.3 and 6.4 programs also provided support. This multigroup participation significantly contributed to an expansion of the body of knowledge, tools and techniques available.

Over a period of years four general categories of effort were pursued: (1) program definition and philosophy, (2) data collection and documentation, (3) development of environmental criteria guidelines, and (4) development of tools and techniques. These four categories of effort were derived based on the multiple objectives defined at the beginning of this program. These were:

1. Determine the current philosophy under which materiel and ordnance are designed and tested.

2. Define the state-of-the-art of the military environment and determine the validity of the current working rules and the designer's understanding of them.

3. Define and present a more realistic philosophy.

4. Measure and present, in terms of 3 above, meaningful in-the-field data.

5. Provide a matrix within which present and future environmental data can be displayed to the advantage of each particular program.

6. Provide environmental limits guidelines of direct use to exploratory development and program management personnel.

7. Provide environmental testing tools and techniques which allow world use traceability to a given test.

8. Determine present errors or misuses in scientific and engineering prediction techniques that negate real world traceability of present design.

9. Propose procedures and techniques that will allow use of present environmental testing equipment and, at the same time, provide data more analogous to the real world.

10. Propose new testing techniques and equipment that will provide function-in-real-world predictability for the ordnance tested.

11. Provide inputs to ancillary disciplines; i.e., reliability, accelerated aging, type life, stress analysis, cumulative damage and other engineering boundary conditions loads disciplines.

12. Provide information to other technical disciplines.

13. Integrate resulting technology into all cogent DoD, Navy, Army and Air Force environmental predictive functions via Military Standards and Military Specifications.

14. Integrate resulting technology into free-world ordnance and material developments via The Technical Cooperation Program (TTCP) and umbrella agreement mechanisms.

DISCUSSION

Figures 1 through 4 outline the planned program efforts. Where tasks have been partially or totally completed, one or more report numbers are indicated. As can be seen, not all areas have been covered. Though all the environmental factors required attention, it was thought that work in the thermal environment area would yield the greatest results with the least expense in the shortest time. Also, it was recognized that few, if any, of the other environmental areas could be intelligently approached without a knowledge of the commensurate temperature regime. Based on this premise, the environmental criteria determination program initially addressed the thermal area. (To meet specific needs, some effort was expended in the areas of vibration, shock, and sand/dirt environments.)

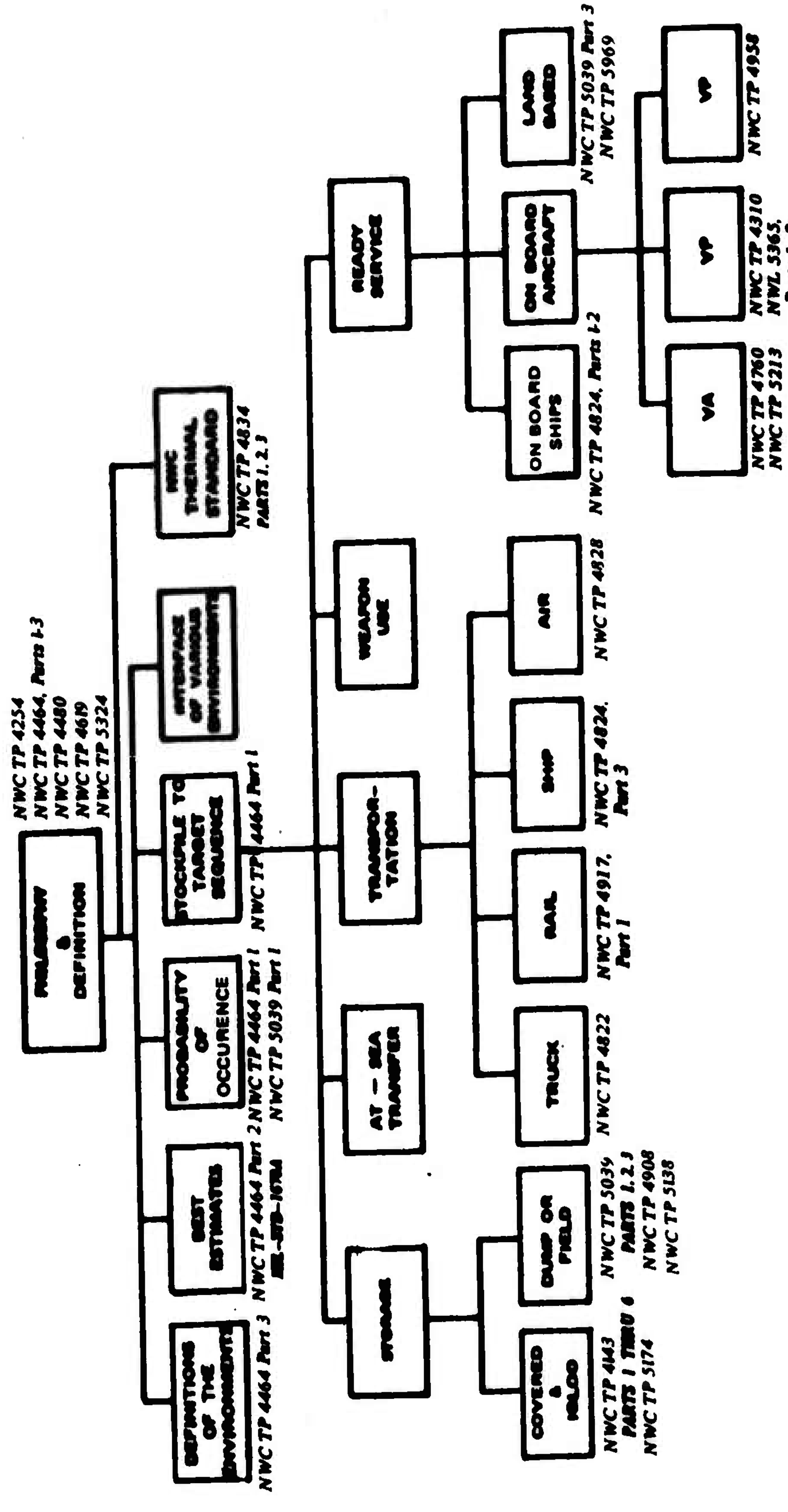

FIGURE 1. Problem Definition.

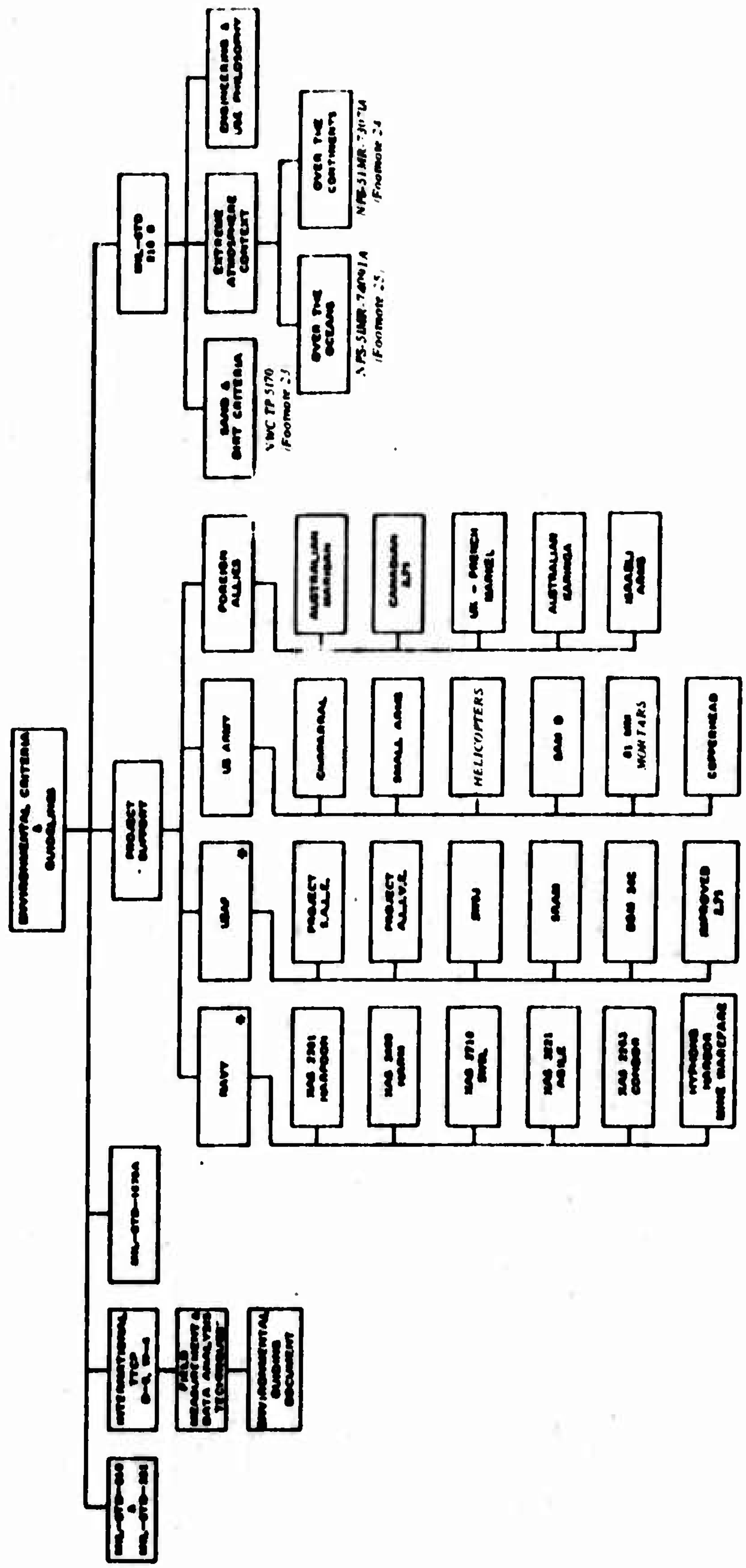

FIGURE 2. Application, Design.

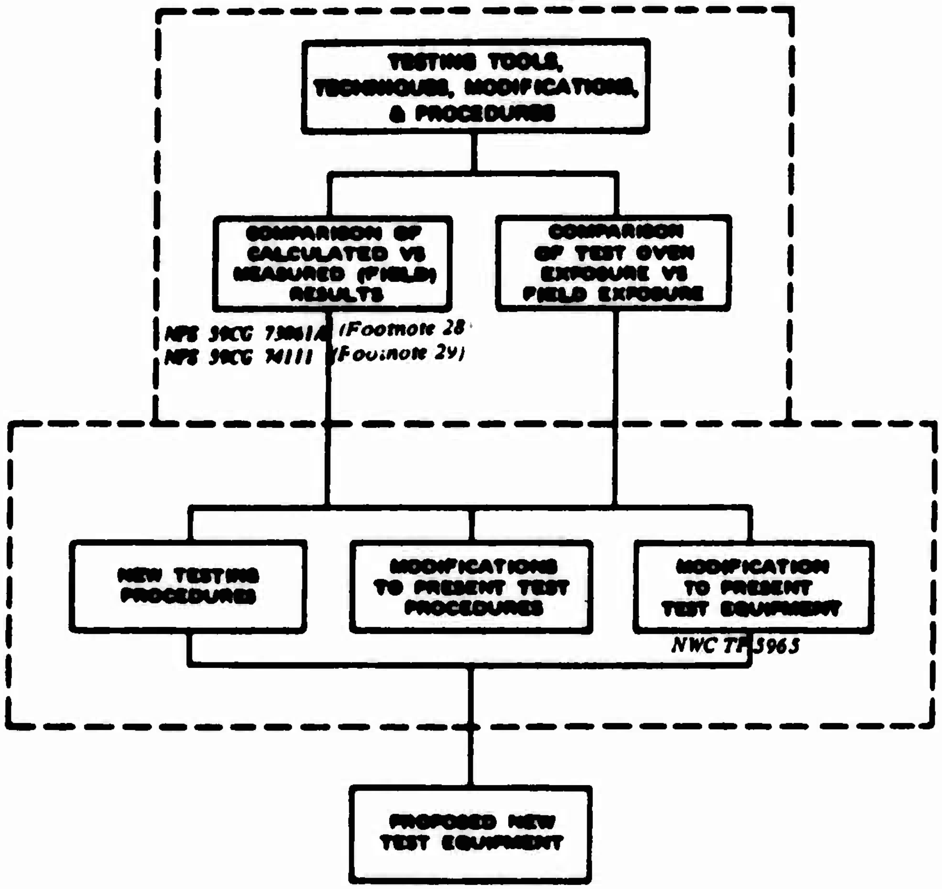

FIGURE 3. Application, Test.

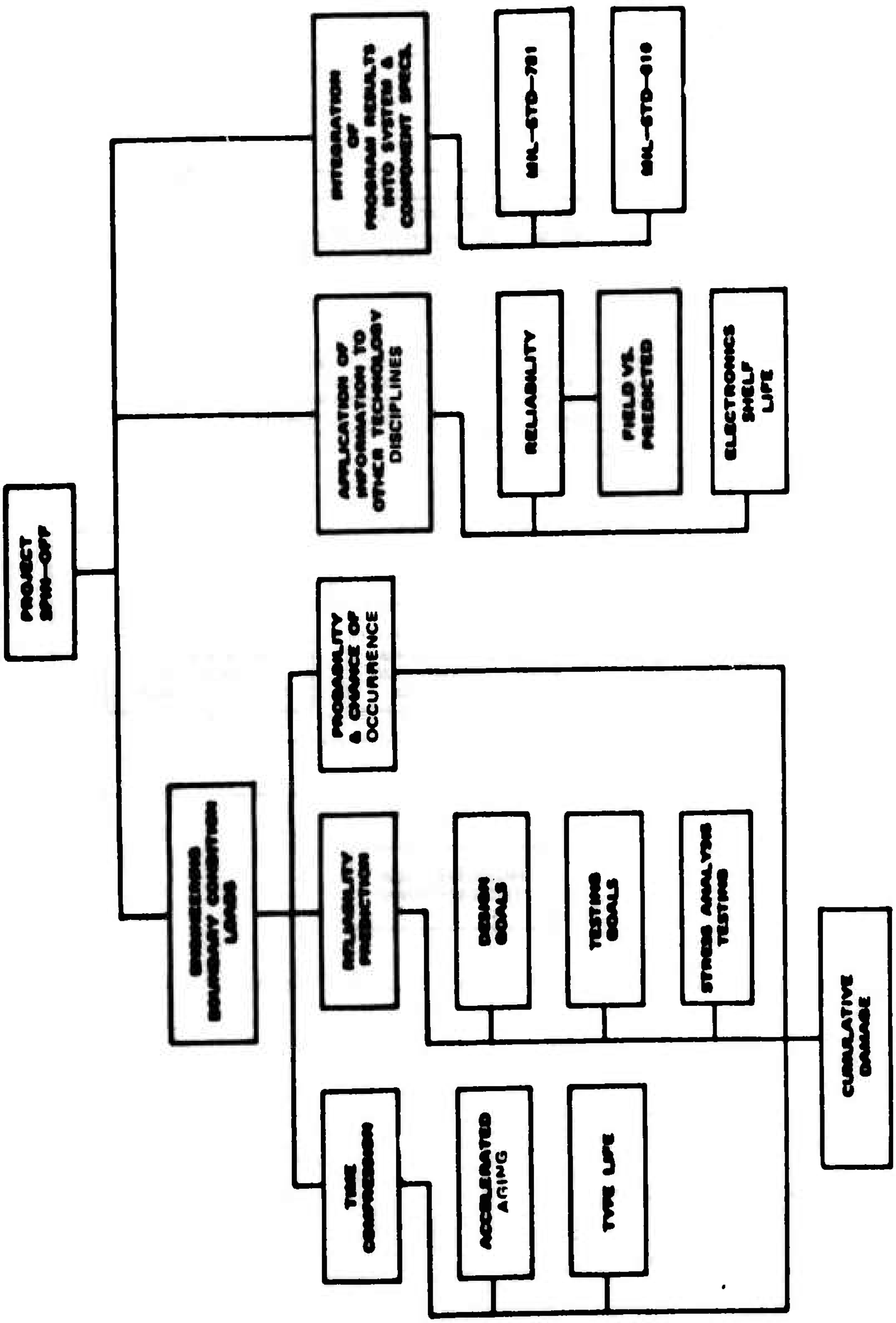

FIGURE 4. Technology Extension.

PROGRAM DEFINITION/PHILOSOPHY

The philosophy underlying this program and the use of information derived from it were first defined and published in 1968.[1] A concept of life events, Figure 5, and cogent environmental factors, Figure 6, affecting the missile was developed such that a matrix, Figure 7, resulted whereby our knowledge, or state-of-the-art, could be continuously checked in any given context.

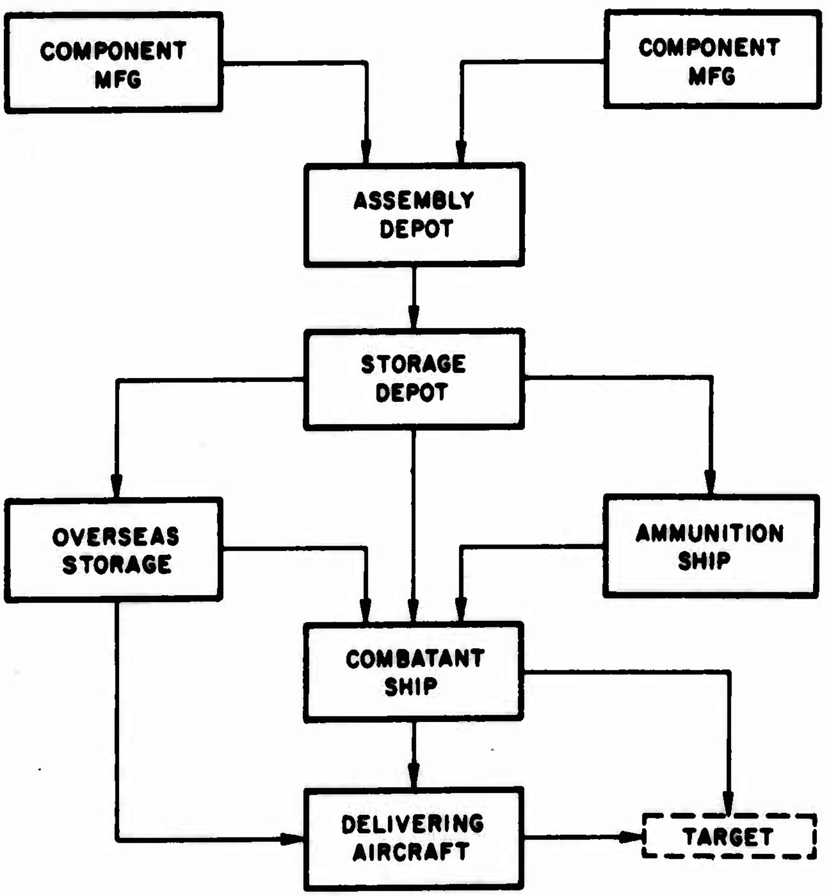

FIGURE 5. Life Events of a Weapon.

[1]Naval Weapons Center. *Environmental Criteria Determination for Air-Launched Tactical Propulsion Systems. Part 1, Stockpile-to-Target Sequence; Part 2, Technical Support for Stockpile-to-Target Sequence; Part 3, Description of the Environment*, by Howard C. Schafer. China Lake, CA, NWC, August 1968. (NWC TP 4464, Parts 1-3, publication UNCLASSIFIED.)

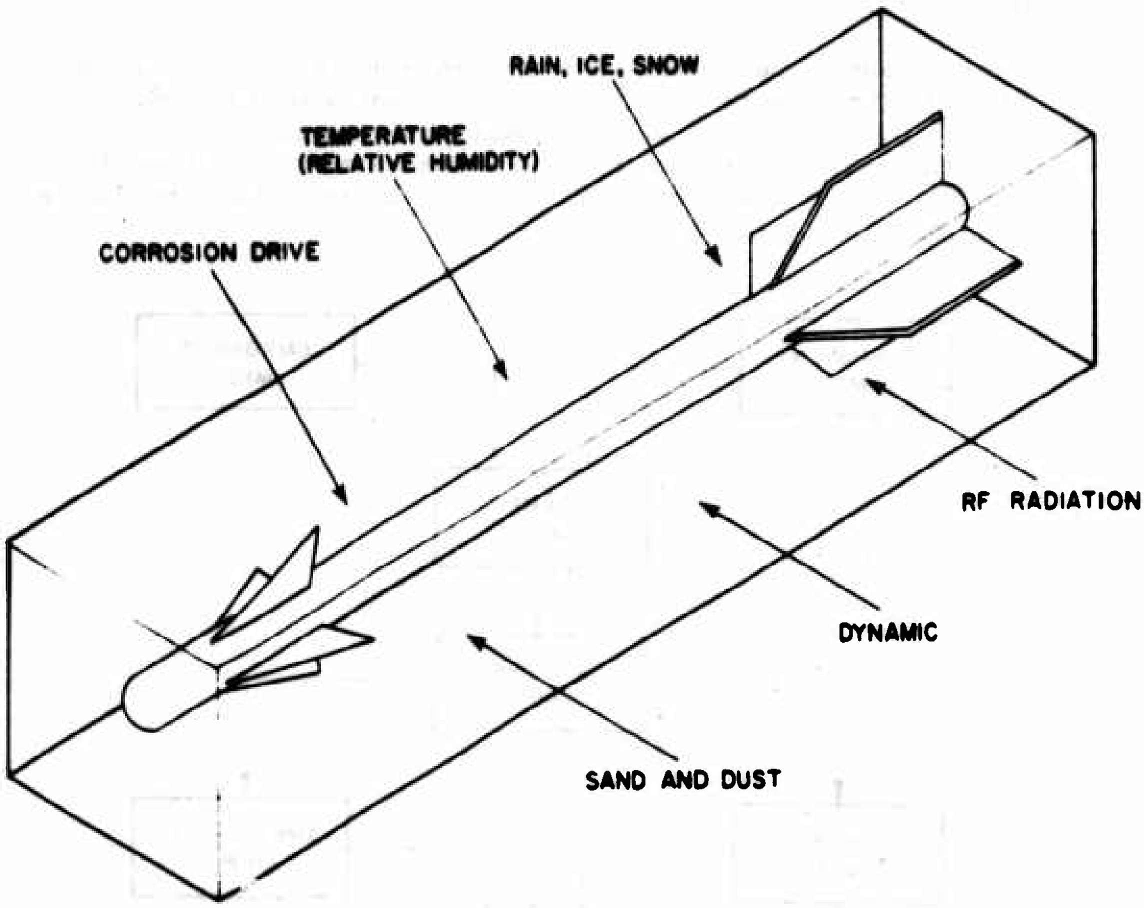

FIGURE 6. Environmental Factors (Forcing Functions).

This primitive ordering of the physical relationships pertaining to this area of technology, as shown in Figures 5 through 7, showed that some generalizations could be made by which a program of work could be defined. Notice in Figure 6 that all the forcing functions act upon the missile. But in the area of missile design, we are really concerned with how the material reacts to these forcing functions. In fact, we cannot coherently address the area of missile surface temperatures without a given design in mind. The response of the unit, then, is the key, not the ill-defined meteorological forcing functions.

In considering past ordnance environmental test programs, it was evident that maximum temperature values, seen only in dump storage, and maximum vibration criterion, seen only in transportation, are often combined in a single test. Reality would require that only criteria unique to a given event, as shown in the Figure 7 matrix, could be combined. Credible criterion data have been derived for various ordnance programs which could be used to fill in many blocks of the Figure 7

EVENT	TRANSPORTATION				STORAGE		AT SEA TR'NS'FR	CARRIER BASED	LAND BASED	AIR-CRAFT CARRIED	LAUNCH TO TARGET
ENVIRON-MENTS	TRUCK	RAIL	AIR	SHIP	IGLOO	DUMP		STG/HAND'G	STG/HAND'G		
TEMP · TIME MAX	O	O	O	O	O	O	O	O	O	O	O
TEMP · TIME MIN	O	O	O	O	O	O	O	O	O	O	O
RELATIVE HUMIDITY	O	O	O	O	O	O	O	O	O	O	O
RAIN	O	O	...	...	O	O	O	...	...	O	O
ICE · HAIL	O	O	...	...	O	O	O	...	...	O	O
SNOW	O	O	...	...	O	O	O	...	...	O	O
CORROSIVE ATMOSPHERE	O	O	O	O	O	O	O	O	O	O	O
SAND · DUST	O	O	O	...	O	O	...	...	...	O	...
SHOCK	O	O	O	O	...	...	O	O	O	O	O
DROP-NO DAMAGE	O	O	O	O	O	O	O	O	O	...	...
VIBRATION	O	O	O	O	...	...	O	O	O	O	O
RF RAD'N HAZARD	O	O	O	O	O	O	O	O	O	O	O

FIGURE 7. Matrix of Life Events and Environmental Factors.

matrix if desired (see Footnote 1). However, only a small number of blocks in the Figure 7 matrix could be classified as complete and known. Therefore, this program was structured around obtaining actual field data measurements and putting these data into a form appropriate for use by missile designers.

DATA COLLECTION/DOCUMENTATION

To fill in the unknown areas of the matrix, a measurement program was undertaken to provide thermal data from a worldwide viewpoint. The first area of interest was igloo and covered storage, Figures 8 and 9, respectively. Existing worldwide igloo and covered storage data, representing about 85% of the exposure life of any materiel, were collected and summarized.[2,3] However, the extremes of exposure for a given missile are found during field or dump storage and during aircraft carry. Therefore, a measurement program was initiated in these areas.

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[2]Naval Weapons Center. *Storage Temperature of Explosive Hazard Magazines. Part 1, American Desert; Part 2, Western Pacific; Part 3, Okinawa and Japan; Part 4, Cold Extremes; Part 5, Caribbean and Mid-Atlantic; Part 6, Continental United States*, by Howard C. Schafer. China Lake, CA, NWC, Part 1, November 1966, Part 2, June 1967; Part 3, June 1967; Part 4, May 1968; Part 5, March 1969; Part 6, November 1969. (NWC TP 4143, Parts 1-6, publication UNCLASSIFIED.)

[3]-----. *Summary of Selected Worldwide Temperatures in Explosive Hazard Magazines*, by I. S. Kurotori and H. C. Schafer. China Lake, CA, NWC, February 1972. (NWC TP 5174, publication UNCLASSIFIED.)

FIGURE 8a. Typical Ammunition and Ordnance Storage Igloos.

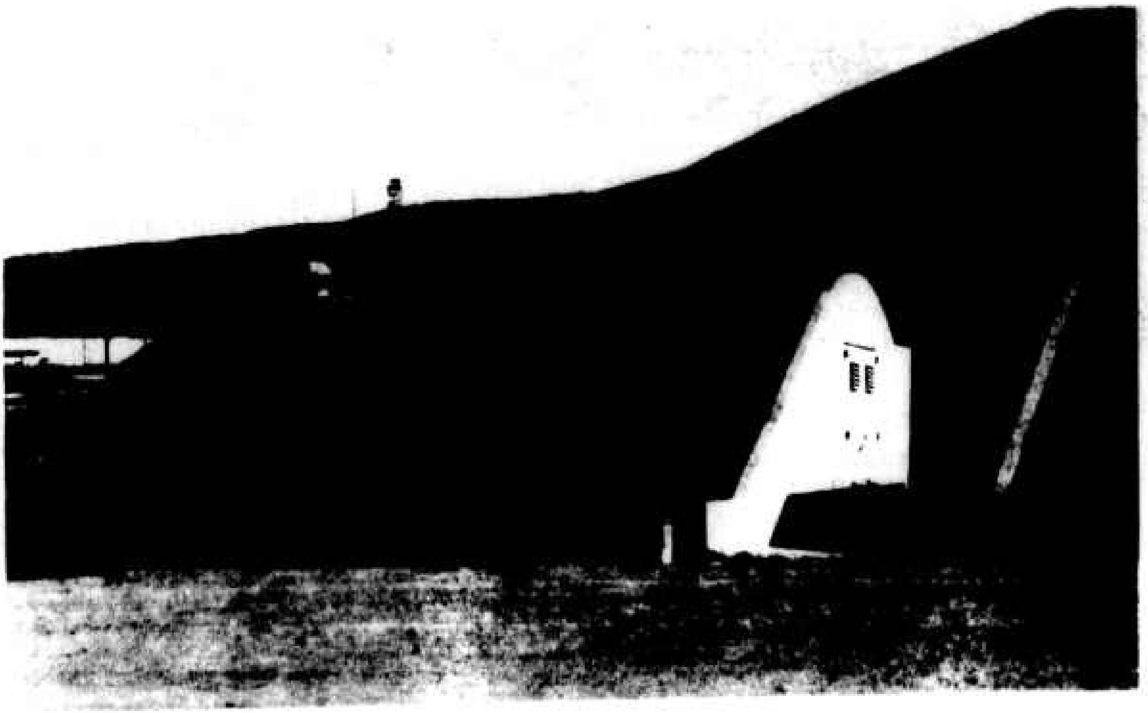

FIGURE 8b. Typical Magazine.

FIGURE 8c. Magazine at the Naval Ammunition Depot, Oahu.

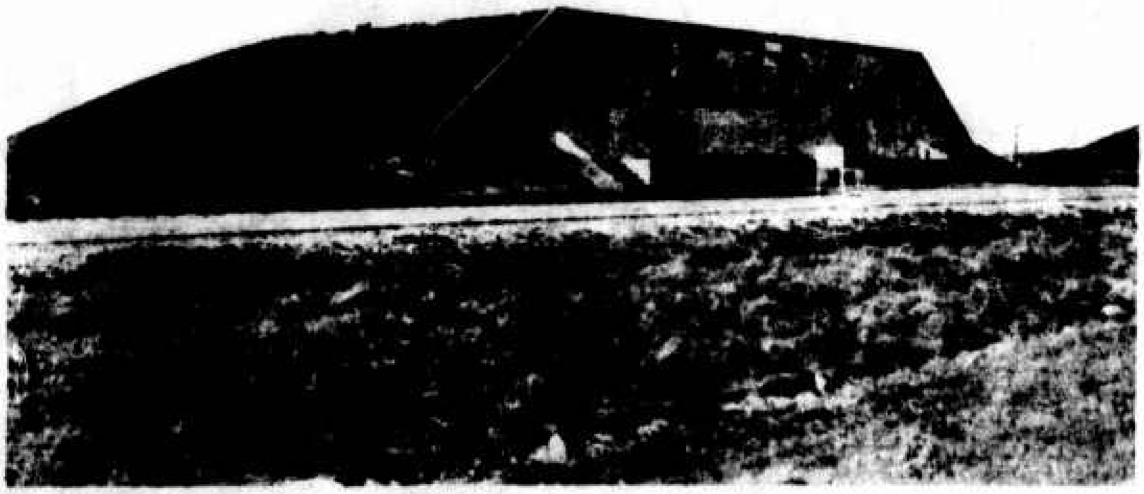

FIGURE 8d. Typical of the Newer Magazines.

FIGURE 9a. Typical of Temporary Shelters for Explosive Ordnance.

FIGURE 9b. Outside Storage Varies From No Covering, Tarpaulin Covering to Light Shelter.

FIGURE 9c. Temporary Shelter Built Around the Magazines in Emergencies.

Since 1967, approximately 18 million data points have been acquired to determine the probable chance of occurrence of temperatures for ordnance in situations of dump storage, truck transport (Figure 10), rail transport (Figure 11), and land-based ready-service exposure aboard aircraft (Figure 12). A portion of the dump storage data has been published.[4-6] Data published and unpublished are available covering the following categories:

Desert

China Lake (Figure 13), and Death Valley (Figure 14).

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[4]Naval Weapons Center. *Measured Temperatures of Solid Rocket Motors Dump Stored in the Tropics and Desert. Part 1, Discussion and Results; Part 2, Data Sample; Part 3, Desert Storage*, by H. C. Schafer. China Lake, CA, NWC, Part 1, November 1972; Part 2, November 1972; Part 3, May 1977. (NWC TP 5039 Parts 1-3, publication UNCLASSIFIED.)

[5]-----. *Dump Storage Temperatures of the Fuel Air Explosive (FAE) Weapons in Shipping Containers - Desert*, by Howard C. Schafer. China Lake, CA, NWC, May 1971. (NWC TP 5138, publication UNCLASSIFIED.)

[6]-----. *Dump Storage Temperatures of the Fuel Air Explosive (FAE) Weapon - Desert*, by H. C. Schafer. China Lake, CA, NWC, August 1970. (NWC TP 4908, publication UNCLASSIFIED.)

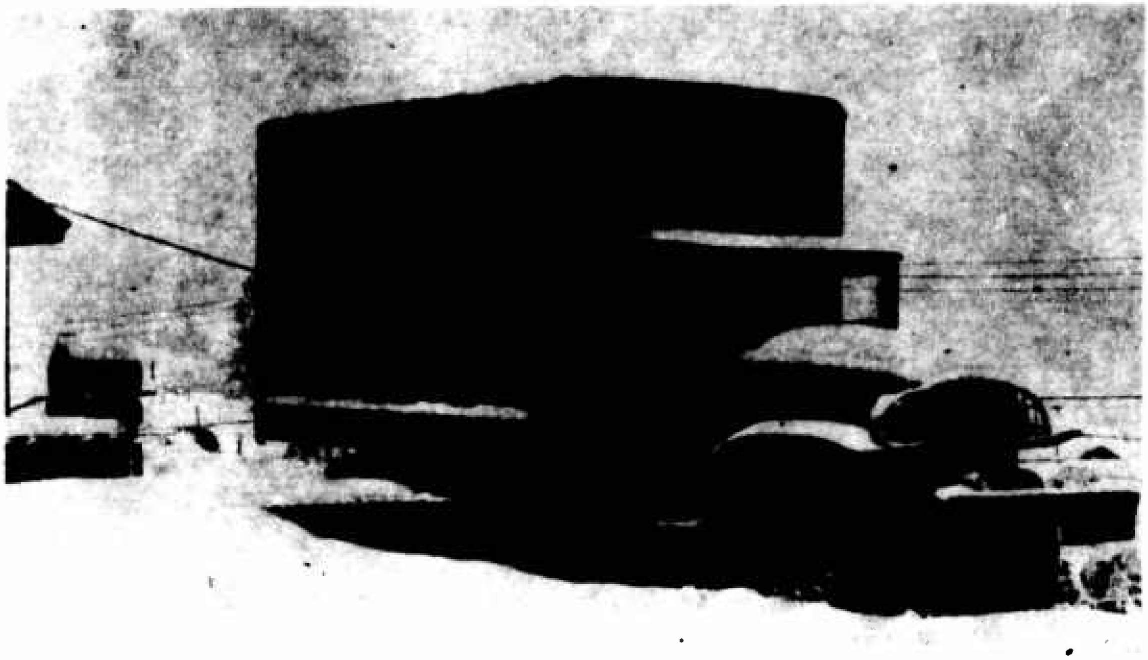

FIGURE 10a. Typical Quiescent Truck Transportation Measurement Matrix (Winter).

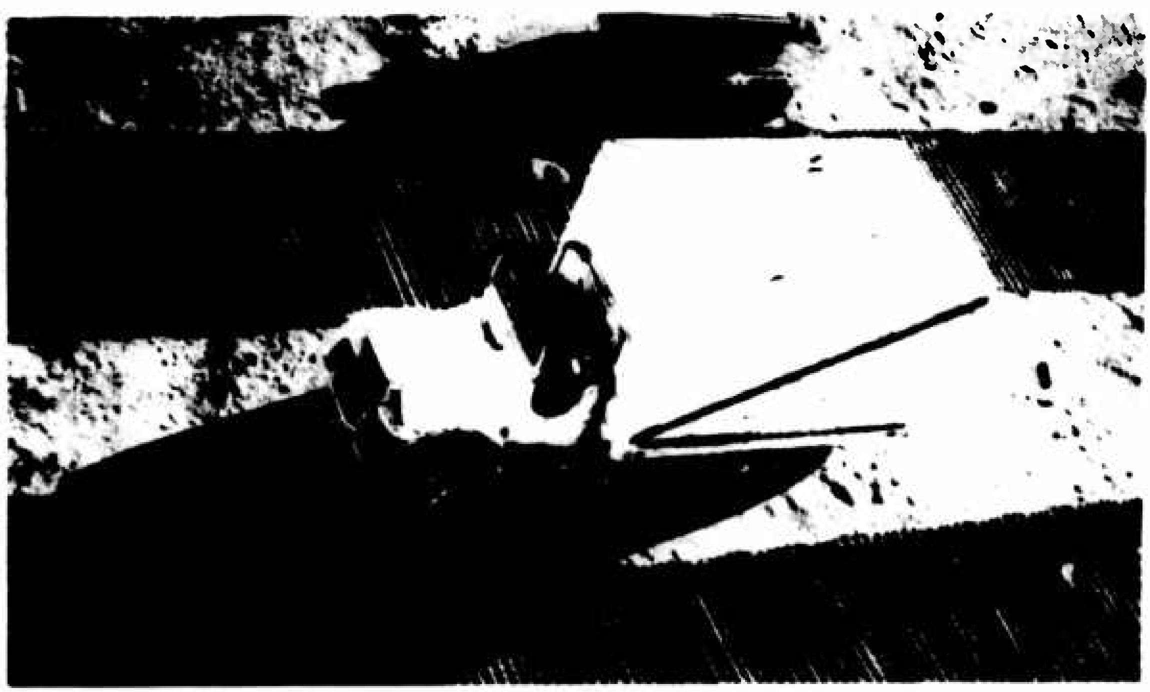

FIGURE 10b. Typical Quiescent Truck Transportation Measurement Matrix (Summer).

FIGURE 11. Typical Quiescent Rail Transportation Measurement Matrix.

FIGURE 12a. Aircraft, Land Based Ready Service Measurement Matrix.

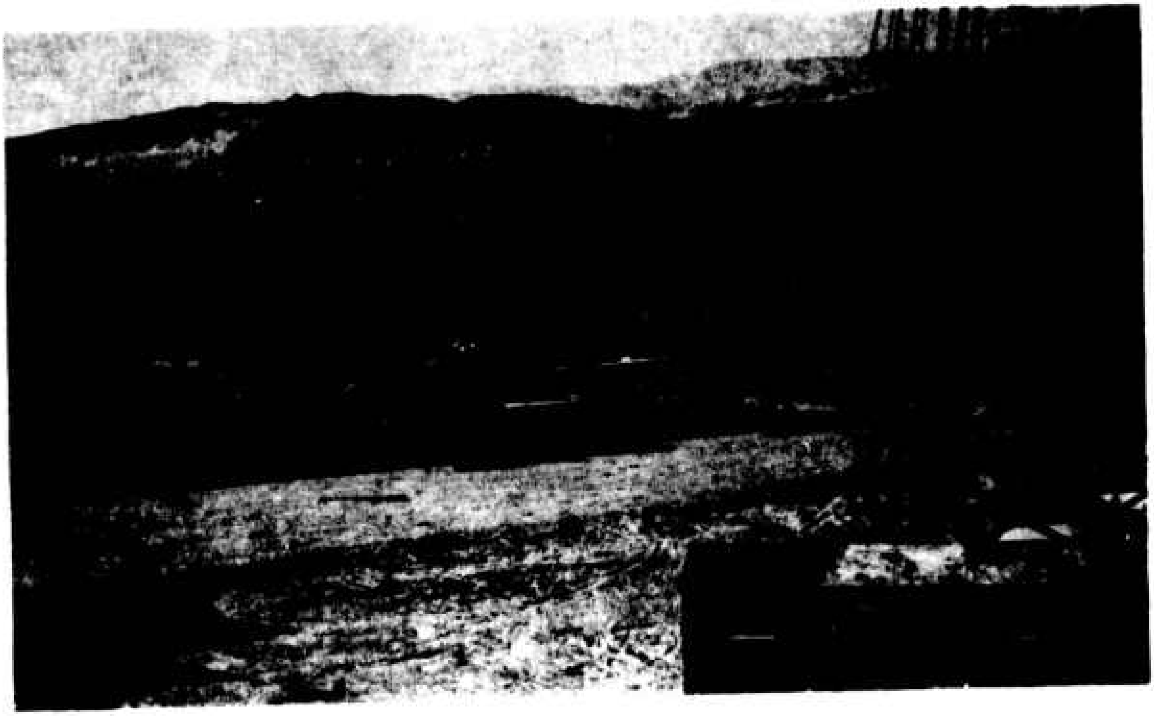

FIGURE 12b. Close-up of Aircraft Land Based Matrix.

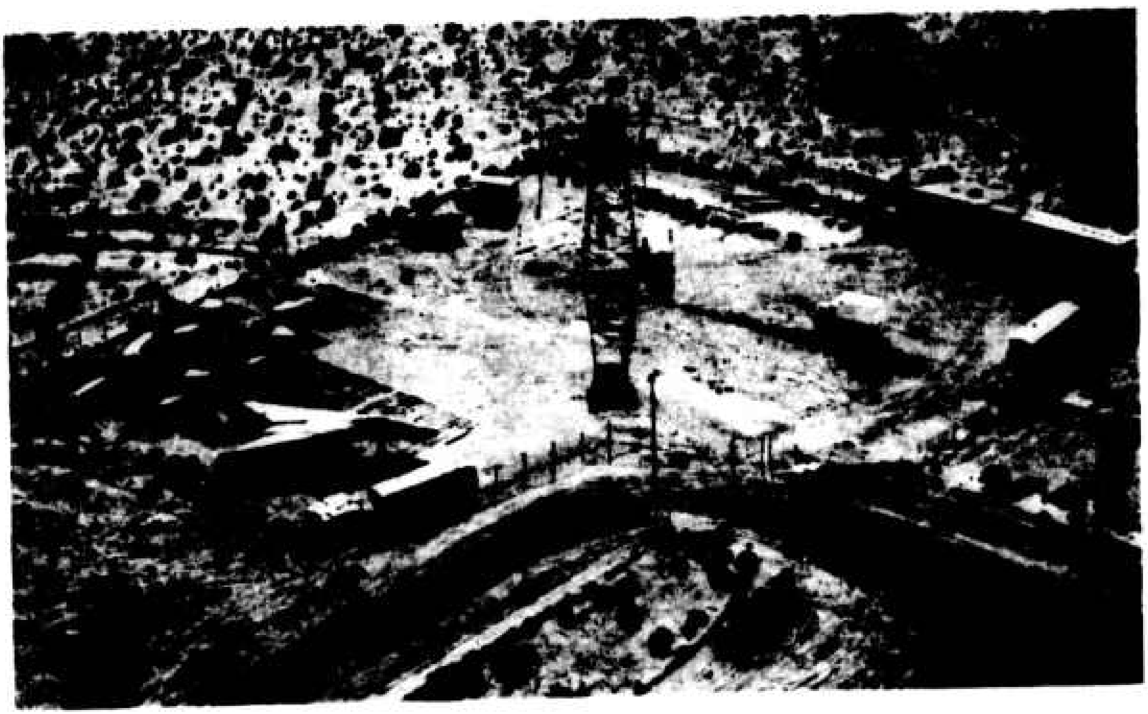

FIGURE 13. China Lake Dump Storage Measurement Site.

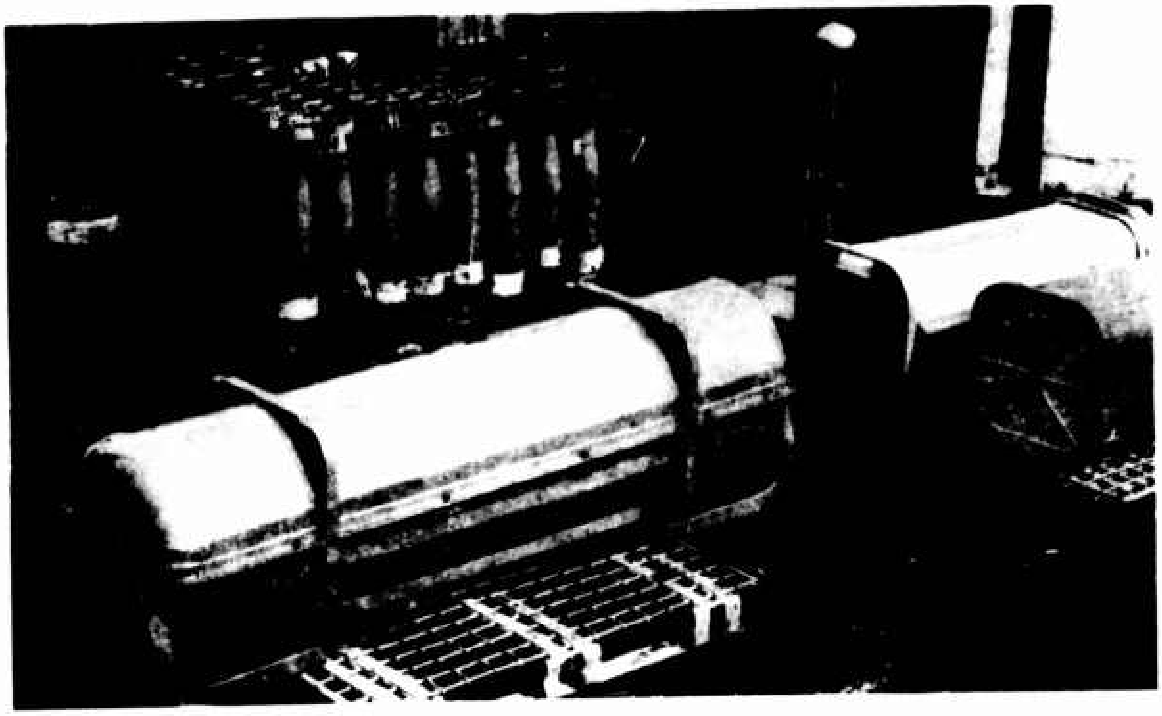

FIGURE 16. Subic Bay Dump Storage Measurement Site.

FIGURE 17. Thailand Measurement Site.

FIGURE 14. Death Valley Measurement Site.

Tropics

Panama (Figure 15); Subic Bay, Philippines (Figure 16); Thailand (Figure 17); and Queensland, Australia (Figure 18).

Arctic

Fairbanks (Figure 19), and Anchorage (Figure 20), Alaska; Resolute Bay and C.F. Base, Alert, Ellesmere Island, Canada.

Mountain Cold

Sierra Nevada Mountains (Figure 21).

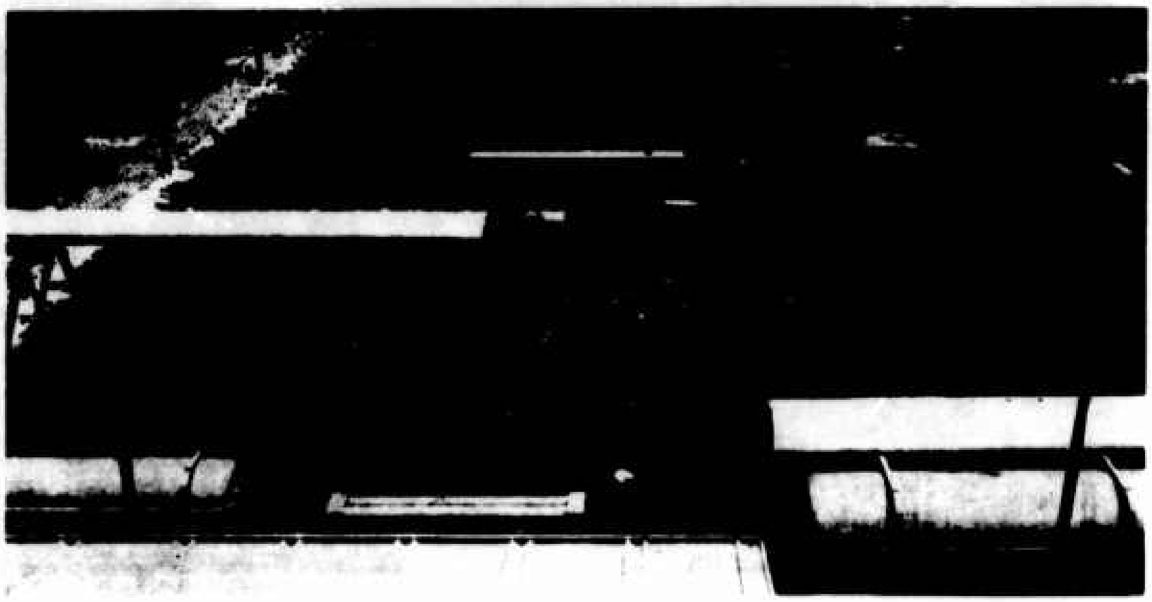

FIGURE 15. Panama Dump Storage Measurement Site.

FIGURE 18. Australian Tropic Dump Storage Measurement Site.

FIGURE 19a. Arctic Dump Storage Measurement Site (Summer).

FIGURE 19b. Arctic Dump Storage Measurement Site (Winter).

FIGURE 20. Marine Arctic Dump Storage Measurement Site.

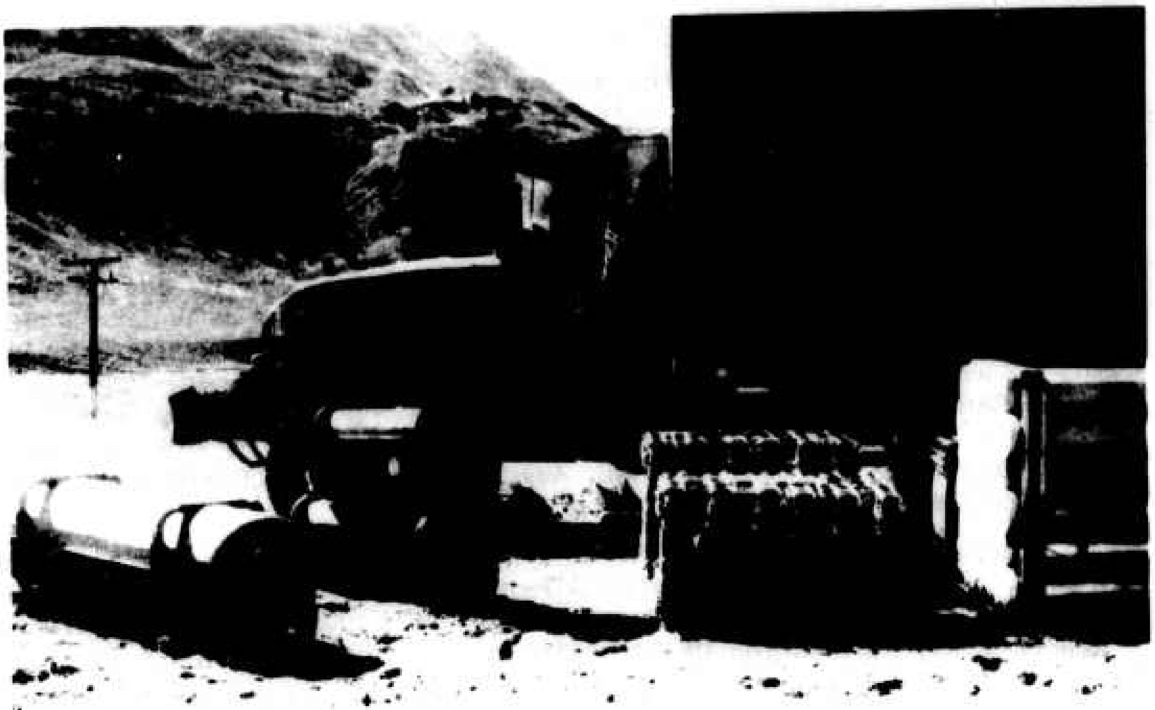

FIGURE 21a. Alpine - Cold Mountain Dump Storage Measurement Site (Summer).

FIGURE 21b. Alpine - Cold Mountain Dump Storage Measurement Site (Winter).

Data measurements for the air-carried thermal environment have been fairly well documented.[7-15] This was made possible through support from specific projects. Of the nine reports published (Footnotes 7 through 15), four cover aerodynamic heating, one covers patrol bombers, and the remainder cover aerodynamic cooling.

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[7]Naval Weapons Center. *Aerodynamic Heating and Cooling Temperature Criteria Determination for Air-Launched Liquid Rocket Motors*, by Howard C. Schafer. China Lake, CA, NWC, August 1969. (NWC TP 4760, publication UNCLASSIFIED.)

[8]Naval Ordnance Test Station. *In-Flight-Temperature Environments of Jet Fighter and Attack Bomber Aircraft Instrumentation*, by Howard C. Schafer. China Lake, CA, NOTS, December 1962. (NOTS TP 2973, NAVWEPS Report 7939, publication UNCLASSIFIED.)

[9]-----. *Actual Environments of Jet Fighter and Attack Bomber Aircraft Instrumentation*, by Howard C. Schafer. China Lake, CA, NOTS, August 1962. (NOTS TP 2910, NAVWEPS Report 7904, publication UNCLASSIFIED.)

[10]-----. *Environmental Tests of Rocket Catapult Mk 2 Mod (Aircraft Ejection Seat) (Winter Series)*, by Howard C. Schafer. China Lake, CA, NOTS, May 1962. (NOTS, TP 2858, NAVWEPS Report 7875, publication UNCLASSIFIED.)

[11]-----. *RAPEC-Cockpit Environments - Live Aircraft*, by Howard C. Schafer. China Lake, CA, NOTS, November 1961. (NOTS TP 2758, NAVWEPS Report 7777, publication UNCLASSIFIED.)

[12]-----. *Environmental Tests of Rocket Catapult Mk 1 Mod 0 (Aircraft Ejection Seat)*, by Howard C. Schafer. China Lake, CA, NOTS, March 1961. (NOTS TP 2638, NAVWEPS Report 7631, publication UNCLASSIFIED.)

[13]-----. *Aerodynamic Heating Temperature Criteria Determination for Sparrow Rocket Motors*, by Howard C. Schafer. China Lake, CA, NWC, December 1967. (NWC TP 4310, publication UNCLASSIFIED.)

[14]-----. *Measurement of Missile Thermal Response During Captive Flight at High Altitudes. Part 1, Program Summary and Results; Part 2, Detailed Description of Equipment and Results*, by Howard C. Schafer, NWC, and Squadron Leader Barry J. Murphy, Royal Australian Air Force. China Lake, CA, NWC, March 1973. (NWC TP 5365, Parts 1 and 2, publication UNCLASSIFIED.)

[15]-----. *A Survey of Aerodynamic Cooling Temperatures of Missiles During External Carry on P-3 Aircraft*, by B. D. Martin and H. C. Schafer. China Lake, CA, NWC, November 1970. (NWC TP 4958, publication UNCLASSIFIED.)

Commensurate with the dump storage and air-carry measurement efforts, it was considered appropriate to determine the major significant factors of truck, rail, ship and air transportation. A survey was made of the thermodynamics of truck and air transport.[16-17] These survey reports were not, however, statistically based but represented actual use situations of opportunity. Therefore, a measurement effort was undertaken to obtain a statistically significant amount of data on truck transportation at desert, tropic and arctic locations. A similar effort was initiated for rail transport.

This program also took full advantage of other data measurement activities already in progress. Such measurements, though being recorded for other than environmental purposes, have been of great value to this program. For instance, the Navy requires that, for safety reasons, shore installation and ship magazine temperature data be recorded on a daily basis. Subsequent to a request from this program, ships from all the numbered U.S. Fleets responded with data. The first two in a series of reports covering ship magazine air temperatures have already been published.[18,19] The third report, "Ammunition Ships", is in process and will be based on over 300,000 data points from AD, LPD, AR, AS, ASR, MSC, MSO and CC class ships.[20] The data for this report series came from the 03, 02, 01, 1, 2, 3, 4, 5, 6, 7 and 8 deck levels, as pertinent, and are presented in relation to the deck level, as well as above and below the waterline, and complete-ship cumulative-probable-chance-of-occurrence versus temperature display.

Also available at NWC are data on submarine and small destroyer type (DD & DE) ships. However, there has been no call for these temperature data and no data reduction effort has been initiated.

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[16] Naval Weapons Center. *Temperature Profiles of Truck Transported Ordnance*, by R. D. Martin and H. C. Schafer. China Lake, CA, NWC, June 1970. (NWC TP 4822, publication UNCLASSIFIED.)

[17] -----. *Temperature Profiles of Air Transported Material*, by H. C. Schafer and R. A. Dickus. China Lake, CA, NWC, October 1970. (NWC TP 4828, publication UNCLASSIFIED.)

[18] -----. *Thermal Exposure of Ammunition Onboard Ship, Part 1. Cruisers and Large Destroyers*, by Sakaye Matsuda and H. C. Schafer. China Lake, CA, NWC, March 1970. (NWC TP 4824, Part 1, publication UNCLASSIFIED.)

[19] -----. *Thermal Exposure of Ammunition Onboard Ship, Part 2. Aircraft Carriers*, by Sakaye Matsuda and H. C. Schafer. China Lake, CA, NWC, October 1979. (NWC TP 4824, Part 2, publication UNCLASSIFIED.)

[20] -----. *Thermal Exposure of Ammunition Onboard Ship, Part 3. Ammunition Ships*, by Sakaye Matsuda and H. C. Schafer. China Lake, CA, NWC, in process. (NWC TP 4824, Part 3, publication UNCLASSIFIED.)

As mentioned previously, requests and support from specific weapons development projects have contributed to the store of data being accumulated by this program. For example, the Harpoon Weapon Program required use information on the Strategic Air Command (SAC) B-52 bomber fleet. Many SAC squadrons and wings provided data from which the cumulative-probable-chance-of-occurrence of cold temperature, as it relates to a wing-launched missile, can be compiled. At that time, the data were given only a glance to provide the Harpoon program with the information it required. The wealth of thermal statistical data acquired for bomber carry of weapons, therefore, has not been reduced but is available, should the need arise.

The magnitude of the data reduction effort, and limited availability of manpower and funds has, in the past, been a significant barrier to processing and publishing results of the data measurement effort. Many gaps remain in the documentation of the environmental data for the stockpile-to-target sequence. Areas most in need of coverage include rail and ship transportation, air field, at-sea transfer, and launch-to-target. Data are yet to be gathered for some of these areas. However, where data are available, a recent breakthrough in the data reduction bottleneck now allows the limited resources available to this program to do more than would otherwise be expected.[21] This new data handling technique has effectively broken the log jam of unreduced thermal field measured data; data previously projected for reduction 3 or 4 years in the future are already being processed into usable format.

With the data reduction breakthrough, and the ability to put together similar ordnance measured data from all worldwide extreme locations, it should be practical to talk about a "worldwide" set of design criteria. When statistical data from arctic, desert and tropic locations are superimposed and properly weighted, it becomes apparent that a cumulative-probable-chance-of-occurrence versus temperature curve can be derived that will have meaning to the design and test community. The drawback to this approach at present is the fact that there are no temperate zone data available with which to fill in the non-extreme center portion of the curve. These data are necessary if we are to specify a probable-chance-of-occurrence with any temperature value or time-temperature curve we might provide to the user.

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[21] Naval Weapons Center. *Evolution of the NWC Thermal Standard. Part 1, Concept; Part 2, Comparison of Theory with Experiment; Part 3, Application and Evaluation of the Thermal Standard in the Field*, by Richard D. Ulrich and H. C. Schafer. China Lake, CA, NWC, Part 1, February 1970; Part 2, August 1971; Part 3, May 1977. (NWC TP 4834, Parts 1, 2 and 3, publication UNCLASSIFIED).

GUIDELINES

Evaluation of the measured data strongly indicated that the thermal response of ordnance in dump storage followed definite patterns; ordnance could, therefore, be divided into thermal response families. The concept of a "thermal standard" was subsequently developed (see Footnote 21), and is now in use by both the U.S. and TTCP foreign nations. NWC was issued a U.S. Patent covering this concept.

By this time, NWC's expertise in the area of the thermal environment as it pertains to weapons had become widely recognized. Both domestic and foreign groups were coming to NWC for environmental information pertinent to their weapons and materiel. Domestic requestors included other branches of the Navy, the Army and Air Force, the Atomic Energy Commission, Department of Transportation, National Transportation Safety Board (NTSB), and civilian DoD contractors. Major foreign requestors included the Australian Department of Supply, Royal Australian Air Force, Canadian Forces, West Germany, Israel and the United Kingdom. Inquiries have also come from Belgium, India, Japan, Indonesia, Republic of China, Egypt, Iran, and Rumania. These users in return gave a good account of the philosophical, practical and legal problems involved in the use of the "environment" in design.

Commensurate with the above liaison activities, DoD Directive 5000.1 was published leading to the Test and Evaluation Master Plan concept. As a result, MIL-STD-810, *Environmental Test Methods*, the prime testing document, and MIL-STD-210, *Environmental Extremes for Military Equipment*, came into question and were proposed for revision.

All the above activities led to a redirection of this program to provide usable tools and techniques for environmental criteria, design, and testing of naval weapons. The mass of data accumulated has proved invaluable to this effort. No where in the world does there exist as extensive a field measured thermal data bank. Due to the efforts of this program, both government and industry have come to recognize that a method is available by which environmental problems can be intelligently addressed.

Data from this program continue to be fed into the environmental criteria and guidelines of both new systems and systems under modification. Implementation of data derived under this program, as well as from other sources, centers on MIL-STD-1670A.[22] This document

[22] Department of Defense. *Environmental Criteria and Guidelines for Air-Launched Weapons*. Miltary Standard 1670 A, 30 July 1976.

represents the first codified set of use-based guidelines detailing the military environment. Data from this program were also used in revising MIL-STD-210B and will be extensively used in the "D" revision of MIL-STD-810.[23-25]

As stated, both new and modified existing weapons systems have been impacted by this program. Some of the major weapons programs impacted to date are listed below:

Navy

Harpoon (XAS 2381)	HARM (XAS 3400)	SW9L (XAS 2718)
Agile (XAS 3221)	Condor (XAS 2263)	Shrike
Sparrow	SW9H	Helicopter Trap Weapon
CBU-55	RAPEC	ARBS
NFM	Phoenix	F-18
ASROC	RAP	BOMROC
CHAFFROC	Advanced 3-Inch Gun	FAE II
Smoky SAM	Mk 48 Torpedo	Advanced Standard Missile
ZEPPO		

Air Force

Improved 2.75 Rocket	RPV (BGM 34C)	B-1 Bomber
ASALM	SRBDM	SRAM
Maverick	SW9J	SALES
ALIVE	Mx	GATOR
IMRAAM		

Army

Chaparral	SAM-D	81 mm Mortar
Frangible Small Arms	Helicopter design	AR 70-38
AR 706-115	Copperhead	SLUFAE

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[23]Naval Weapons Center. *Survey and Study on Sand and Dirt*, by Edward Kuletz and H. C. Schafer. China Lake, CA, NWC, August 1971. (NWC TP 5170, publication UNCLASSIFIED.)

[24]Naval Post Graduate School. *Development of Regional Extreme Model Atmospheres for Aerothermodynamic Calculations*, Monterey, CA, NPS. (NPS-51MR73071A, publication UNCLASSIFIED.)

[25]-----. *Oceanic Extreme Model Atmospheres for Aerothermodynamic Calculations*. (NPS-51MR74091A, publication UNCLASSIFIED.)

Miscellaneous Users

Australia (Mariban and Karingo)
Canada (Advanced 2.75 Rocket)
United Kingdom (Martel Missile)
U.S. DoD Contractors (Boeing, McDonnell-Douglas, Lockheed, Raytheon, RCA, Hughes, Rockwell, Bell Telephone, Martin, Sperry)

TOOLS/TECHNIQUES

The establishment of environmental criteria and guidelines can have little value if adequate tools and techniques for testing are not available. It had been shown that, besides errors in theoretical prediction of the thermal experience of a weapon (calculated using theory and rote methods), the method of duplicating that exposure (laboratory testing) leads to a compounding of the predictive error (comparison with real use). Therefore, the object was to determine the magnitude of the compound error by comparing the error components with an actual field measured problem (Figure 22).

Providing only the usually available meteorological information, three independent thermodynamic groups (one at NWC, one at Brigham Young University, and one at the Naval Postgraduate School, NPS, Monterey) were tasked to predict the thermal experience of a weapon. Their thermal predictions were compared to field measured missile thermal response data, and that error was quantified. The smaller of the two missiles was put into a testing oven programmed to the response temperature measured at the top surface of the rocket motor. The responses measured by the remaining thermocouples located throughout the missile were recorded, and that error was quantified. The next step is to determine how these compounding errors can be modified or eliminated. A report is currently being prepared which will present the exposure/calculation comparison.[26] Additional background information on this work has been published by NPS.[27-29]

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[26] Naval Weapons Center. *Diurnal Temperatures in Dump Stored Missiles*, by H. C. Schafer and R. D. Ulrich. China Lake, CA, NWC, in process. (NWC TP 5923, publication UNCLASSIFIED.)

[27] Naval Postgraduate School. *An Environmental Heat Transfer Study of a Rocket Motor Storage Container System*, thesis by Lt. A. H. Wirzburger, USN, Monterey, CA, NPS.

[28] -----. *An Analytical Model for Predicting the Daily Temperature Cycle of Container Stored Ordnance.* Monterey, CA, NPS. (NPS-59CG73061A, publication UNCLASSIFIED.)

[29] -----. *A Liquid Crystal Thermographic Study of a Heated Cylinder in Cross Flow.* Monterey, CA, NPS. (NPS-59CG74111, publication UNCLASSIFIED.)

FIGURE 22a. Representative Air-Launched Missiles in Dump Storage.

FIGURE 22b. Representative Air-Launched Missiles Awaiting Aircraft Carrier Pickup, Dockside Dump Storage.

FIGURE 22c. Typical Forward Dump Storage Area.

The next major area of effort will be to complete development of the tools and techniques necessary to convert existing environmental criteria into "do-able" tests having some predictive meaning (see Figure 3). Logically, it should first be determined if the present convective heat transfer ovens, with the capacity for a high mid-range convective heat transfer, can be harnessed to even semi-accurately reproduce the dump storage situation. In the field, solar radiation is the major source of heating; usually convection only cools the ordnance. The area of maximum exposure to the sun for a field-stored missile is small compared to the total exposure of the same missile in a forced convection oven. In essence, the quantity of heat transferred to the missile in the present forced convection ovens is three to thirty times more than that occurring in real life (per unit time). This leads to overtesting of internal components of the missile; consequently raising system cost and probably lowering performance.

The first task is to determine if, using presently available Navy test chambers, a method can be found for lowering the exposure of the missile to the flow of heat and yet allow the high temperatures necessary to the missile's top skin. This can be done by using a system of baffles and preferential insulation. A report discussing the feasibility and progress in the use of present ovens for more realistically controlled gradient testing has been published.[30]

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[30] Schafer, Howard C. *Deficiencies in Traditional High-Temperature Storage Testing*. Journal of the Institute of Environmental Sciences, Vol. XX, No. 1, Jan/Feb 1977.

Present environmental test procedures generally call for only a thermal soak situation. Chemicals and electronics perform differently when at any constant temperature as opposed to when they have a thermal gradient imposed across them. In reality they seldom, if ever, are at a constant temperature. Procedures must also be pioneered that provide a logical, usable set of test circumstances to duplicate the real-world thermal environment. Many present test procedures may be salvageable, but efforts should be undertaken to modify these procedures.

Where present state-of-the-art testing equipment simply cannot perform, new testing equipment should be prototyped and proven. Aerodynamic heating of explosive and propellant components is currently not feasible because of safety considerations. However, it can be done accurately and simply by applying present fluid flow and radiation technology, if funding is provided. The feasibility of a different test oven, more novel than present generation chambers but practical nonetheless, has been documented.[31] In general, this oven consists of four separately programmable sides. The heat transfer system is fluid rather than electrical heat or flame. (Using a fluid permits controlled low temperature.) The four separately programmable quadrants are designated east, top, west, and bottom and programmed to duplicate the cyclic variations that would be exhibited by an instrumented missile in dump storage. This brings the real-life induced thermal gradients into the laboratory and, because of the low temperature radiation matrix, there is no chance of cooking-off ordnance that may have been placed into the oven chamber in a sloppy or negligent manner. A patent for this concept has been granted to NWC.

STATUS AND RECOMMENDATIONS

It was first thought that by collecting field measured data and integrating them into Section 3 requirements of the missile design specification the problem of integrating the environment into Naval missiles would be solved. The short-sightedness of this thinking became evident, however, when designs incorporating these data failed to pass the environmental qualification tests (Section 4) of the design specification. A comparison of these two sections of the same specification

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[31] Naval Weapons Center. *Feasibility Demonstration of a Four-Panel Environmental Simulation Oven*, by Howard C. Schafer and Richard D. Ulrich, China Lake, CA, NWC, September 1978. (NWC TP 5965, publication UNCLASSIFIED.)

showed that the environmental design and test data in no way tracked. Thus, a skillful contractor could simply ignore Section 3 and design directly to pass the tests of Section 4. Needless to say, this led to degraded reliability of many units in field use, but it certainly satisfied the contract conditions.

With realization of the above, effort continued to develop a means of converting the measured thermal response data into usable testing information. Basically, this meant taking more interest in revising the major military standards that address the materiel environment. Efforts continue to more fully impact the MIL-STD-210, MIL-STD-810, the USOD DMSSO ENVR program plan, and project peculiar design specifications. The tools and techniques so far provided form the basis for a connecting document that allows Section 3 real-world environmental information (e.g., MIL-STD-210 or equivalent information) to be converted into tailored tests or to modify the procedures of MIL-STD-810 so that they track with Section 3 needs. Where no other method is either available or superior to the data and techniques identified and collected, these form the beginnings of an environmental handbook and are published as an appendix to MIL-STD-1670.

Much work remains to be done under the environmental criteria determination program. The following is a prioritized listing of recognized areas of effort still to be accomplished.

1. Complete the thermal work through to test procedures, techniques, and equipment.

2. Continue to publish existing worldwide field measured thermal data.

3. Impact current and future Military Environmental Standards and Specifications.

4. Provide a ready access to detailed thermal data for Naval air-launched weapons.

5. Integrate thermal work into the related engineering boundary condition loads areas.

6. Integrate thermal and dynamic environments into traceable, predictive, combined tests.

7. Address time compression.

8. Approach cumulative damage from the dynamic/reaction kinetic context.

9. Recodify the damage potential of the various environments in their rank order of damage importance.

10. Integrate the top three into a set of traceable combined (synergistic) tests.

11. Address corrosion through reaction kinetics technique.

12. Place the various water environments into the context of air-launched weapons and aircraft.

13. Expand the sand and dirt effort to include abrasion, chemically destructive aspects, and clogging. Complete worldwide dirt constituent effort.

14. Integrate effort into Military Standards and Specifications.

15. Compile a usable DoD handbook or handbook series on the Military Environment.

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4 Army Engineer Topographic Laboratories, Fort Belvoir
   ETL-GS-EA (1)
   ETL-GS-EC, T. Neidringhaus (2)
   Technical Library (1)
2 Chemical Systems Laboratory, Aberdeen Proving Ground
   Research and Development Laboratory (1)
   Warfare Laboratory (1)
4 Harry Diamond Laboratories, Adelphi
   Technical Director (1)
   R. Hoff (1)
   R. Smith (1)
   Technical Library (1)
2 Office Chief of Research and Development
   Dr. Leo Alpert (1)
   Technical Library (1)
15 Headquarters, U.S. Air Force
   AF/CVB(S) (1)
   AF/SA (1)
   AF/SAG (1)
   AF/RD (1)
   AF/RDC (1)
   AF/RDPS, Allen Eaffy (1)
   AF/RST (1)
   AF/XO (1)
   AS/DASJL (1)
   ASCC/MC (1)
   CCN (1)
   RDQF (1)
   SAFAL (1)
   XOORC (1)
   XOORE (1)
1 Air Force Logistics Command, Wright-Patterson Air Force Base (Technical Library)
1 Air Force Systems Command, Andrews Air Force Base (Technical Library)
1 Strategic Air Command, Offutt Air Force Base (Technical Library)
1 Tactical Air Command, Langley Air Force Base (Technical Library)
1 Air Force Acquisition Logistics Division, Wright-Patterson Air Force Base (Technical Library)

10 Air Force Armament Laboratory, Eglin Air Force Base

AFATL/AW (1)
AFATL/DL (1)
AFATL/SD (1)
AFATL/102 (1)
AFATL/SD2 (1)
AFATL/SD3 (1)
AFATL/SD4 (1)
AFATL/SD8 (1)
AFATL/SDL (1)
Technical Library (1)

2 Air Force Cambridge Research Laboratories, Hanscom Air Force Base
Code LKI, P. Tattleman (1)
Technical Library (1)
1 Air Force Office of Scientific Research (Dr. J. F. Masi)
1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (Technical Director)
1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (RKMA, L. Meyer)
1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (Dr. Trout)
1 Air Force Rocket Propulsion Laboratory, Edwards Air Force Base (Technical Library)
5 Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base
AFWAL/AA (1)
AFWAL/FI (1)
AFWAL/FIE (1)
Head, Research and Technology Division (1)
Technical Library (1)
3 Environmental Technical Applications Center
O. E. Richards (1)
Technical Director (1)
Technical Library (1)
1 Nellis Air Force Base (Technical Library)
2 Ogden Air Materiel Area, Hill Air Force Base
Munitions Safety (1)
Technical Library (1)
2 Rome Air Development Center, Griffiss Air Force Base
Code RCRM (1)
Technical Library (1)
1 Sacramento Air Materiel Area, McClellan Air Force Base
1 Warner Robins Air Materiel Area, Robins Air Force Base (Technical Library)
3 Armament/Munitions Requirements and Development (AMRAD) Committee (2C330, Pentagon)
2 DLA Administrative Support Center (Defense Materiel Specifications and Standards Office)
J. Allen (1)
D. Moss (1)
3 Department of Defense, Explosives Safety Board, Alexandria
3 Deputy Under Secretary of Defense Research and Engineering (Acquisition Policy)
Director, Materiel Acquisition Policy (3E144), J. A. Mattino (1)
Standardization and Support (2A318), Col. T. A. Musson (2)
2 Deputy Under Secretary of Defense Research and Engineering (Research and Advanced Technology)
Director, Engineering Technology, G. R. Makepeace, 3D1089 (1)
R. Thorkildsen (1)
1 Director, Defense Test & Evaluation (Deputy for Test Facilities, W. A. Richardson, 3D1043)
12 Defense Technical Information Center